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| Patentanmeldung Nr. | Patent application No. | Demande de brevet n° |

02080317.7

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For the President of the European Patent Office

Le Président de l'Office européen des brevets
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R C van Dijk

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Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.
If no title is shown please refer to the description.
Si aucun titre n'est indiqué se referer à la description.)

Electro magnetic drive system

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Electro Magnetic Drive System

1 Field of usage

The inventions described below can be used in an environment of high magnetic sensitivity. More specifically this means that for the proper usage of this equipment stringent requirements are posed on the magnetic fields that remain in the system. These fields can be both static and dynamic, and be caused by natural or cultural causes. Not meeting the requirements on magnetic fields can hamper the proper functioning of this equipment or even destroy (parts of) these systems and the products in it.

2 Possible applications

Examples of these kinds of equipment can be found in the area of imaging equipment with charged particles (e.g. E-beam writers), inspection machines with charged particles, processing machines with charged particles (e.g. SEMICON ion implantation), machining systems with charged particles, medical equipment with the requirement of low magnetic fields (MR, Roentgen).

3 General State of the Art

In many of the applications mentioned above precise motion is very important. Furthermore in some of these applications vacuum requirements are also posed for proper functioning. These combined restrictions (magnetic fields, precise motion and vacuum environment) are being met in most current systems with mechanical transmissions (spindles, belts and pulleys, mechanical bearings) driven by actuators (mostly electromagnetic) outside the volume of the most stringent vacuum and magnetic field requirements.

From a precision motion point of view however, the "direct-drive" principle has many advantages. First of all the force of motion can be applied directly to the part to be moved. Furthermore no direct mechanical contact is necessary between the moving part and the rest of the system, improving the vibration isolation from the rest of the system to the moving part.

Most direct drive systems are based on electro-magnetic principles (reluctance, Lorentz forces). These however, are extremely difficult to use in view of the above mentioned requirements on magnetic fields.

The inventions described below can overcome this difficulty, allowing application of the direct-drive principle together with stringent control over magnetic fields, vacuum environment and precision motion. The inventions can be clustered into the following groups

3.1 SHIELDING OF MAGNETIC FIELDS

1) Using "End-plates" of magnetic drive tracks to shield magnetic fields
2) Shielding of electromagnetic drive
3) Shielding of reluctance based magnetic actuator
4) combined shielding of linear electromagnetic drive and reluctance based magnetic actuator

3.2 REDUCTION OF MAGNETIC FIELDS

5) Using the number of magnets in electromagnetic drive to control magnetic fields
6) Using "half" magnets to control field in electromagnetic drives

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7) Using the length of the magnet-plate of electromagnetic drive to control magnetic fields in the volume of magnetic field requirements
8) Using "multi-pole"-cores in reluctance based magnetic actuators
9) Degaussing method based on degauss auxiliary device for generating magnetic fields (e.g. magnets and/or coils)

3.3 VIBRATION ISOLATION WITH RELUCTANCE BASED MAGNETIC ACTUATOR

10) Flux amplifier control
11) Model based control of reluctance actuator to achieve gap-independent force-characteristics

3.4 STAGE CONCEPTS

12) Model-based compensation of drive-forces
13) Stage with gap-independent control of reluctance based actuator force
14) Long stroke Lorentz actuator as bearing

3.5 MISCELLANEOUS

15) 2-DOF planar electro-magnetic actuator
16) Using permanent magnets for generating offset forces in active magnetic bearings, using different gap dimensions for the permanent magnetic system and the active magnetic bearing system.

4   Description of inventions

4.1   USING "END-PLATES" OF MAGNETIC DRIVE TRACKS TO SHIELD MAGNETIC FIELDS (INVENTOR: ANGELO DE KLERK)

4.1.1   Known solutions
At this moment there are no known solutions.

4.1.2   Literature references:
No references found.

4.1.3   Problem definition
All magnetic components behave as a dipole or multi-pole at large distances from the magnetic component. It is therefore necessary to shield the source of the magnetic field as good as possible.

4.1.4   Measures and insights
The magnetic fields can be reduced by localizing the magnet field, i.e. keep the magnet field close to the source. On the other hand one side of the magnet drive track should always be accessible. Therefore the other sides are "closed".

4.1.5   Embodiments
See figure. The sides which are not accessible are "closed" by plates, these plates have the same material as the back plates. This keeps the magnetic field inside the constructed box.

magnet plates

This side accessable

"End" plates
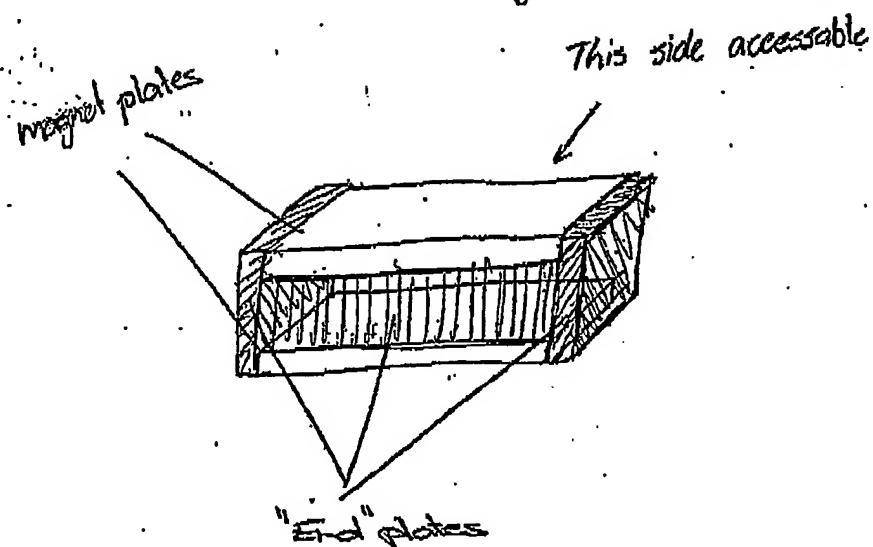
4.2   SHIELDING OF ELECTROMAGNETIC DRIVE (INVENTORS: ANGELO DE KLERK, ARJAN BAKKER)

4.2.1   Known solutions
At this moment there are no known solutions.

4.2.2   Literature references:
No references found.

4.2.3   Problem definition
All magnetic components behave as a dipole or multi-pole at large distances from the magnetic component. It is therefore necessary to shield the source of the magnetic field as good as possible.

4.2.4   Measures and insights
By using shielding the magnetic field can be reduced.

4.2.5   Embodiments
See figure. It is important that one side of the magnet track is accessible. By putting N shields over the magnet track by using a metal with a large permeability, reduces the magnetic field at the plane of interest.

4

plane of interest

metal with normal μr

N shields of metal with high μr

coil   magnets
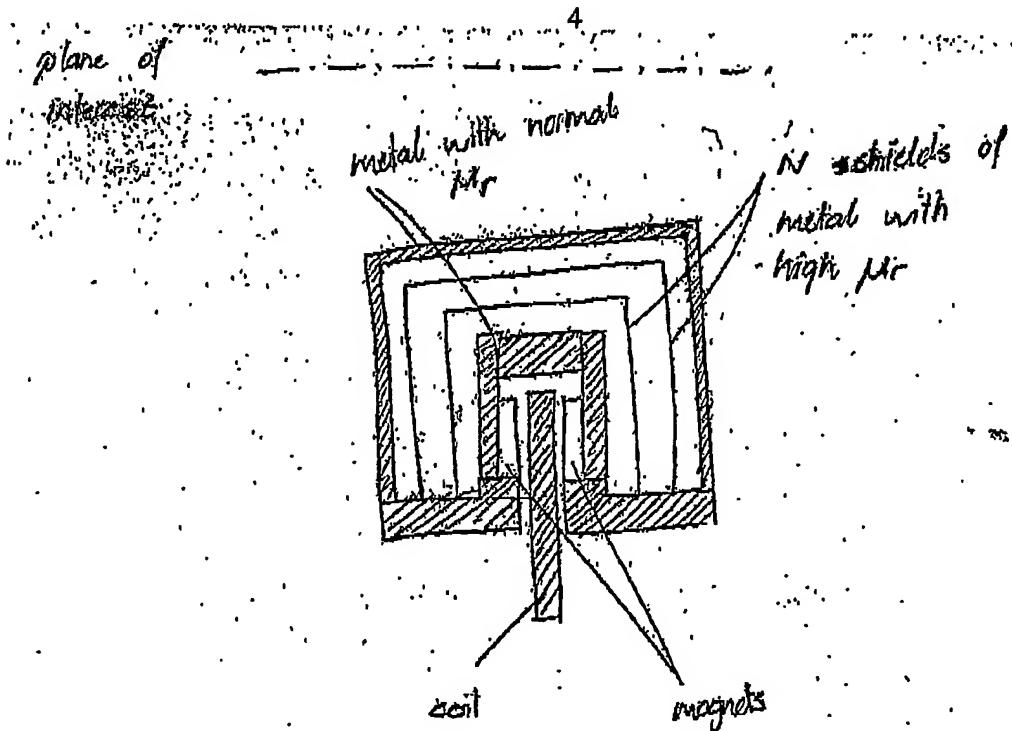
4.3   SHIELDING OF RELUCTANCE BASED MAGNETIC ACTUATOR (INVENTOR: ANGELO DE KLERK)

4.3.1   Known solutions
At this moment there are no known solutions.

4.3.2   Literature references:
No references found.

4.3.3   Problem definition
All magnetic components behave as a dipole or multi-pole at large distances from the magnetic component. It is therefore necessary to shield the source of the magnetic field as good as possible.

4.3.4   Measures and insights
By using shielding the magnetic field can be reduced.

4.3.5   Embodiments
See figure. The reluctance actuator has to move with respect to the counter part, therefore it is necessary to connect one part of the shielding to the reluctance actuator and the other part of the shielding to the counter material.

reluctance actuator

N times shielding of metal with high μr

counter material
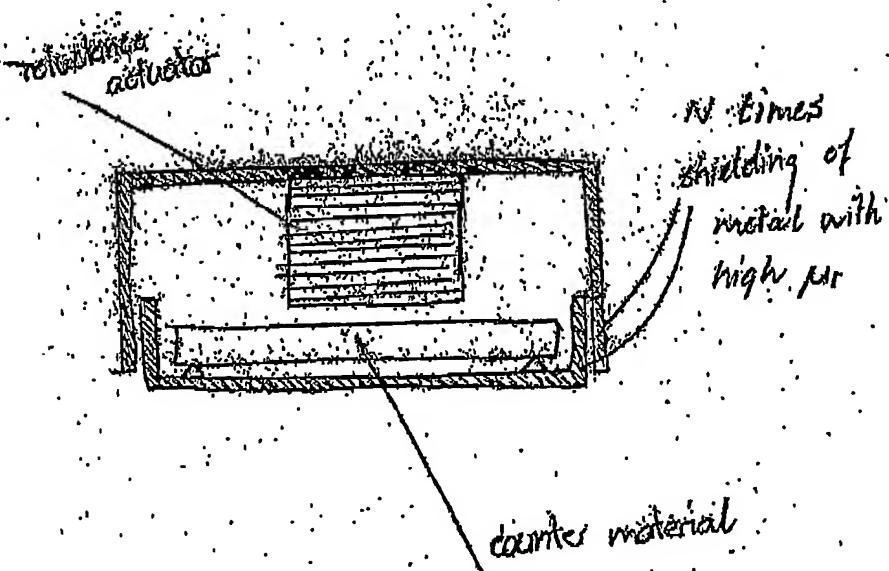
4.4 COMBINED SHIELDING OF LINEAR ELECTROMAGNETIC DRIVE AND RELUCTANCE BASED MAGNETIC ACTUATOR (INVENTORS: ANGELO DE KLERK, ARJAN BAKKER, HUUB VROOMEN)

4.4.1 Known solutions
At this moment there are no known solutions.

4.4.2 Literature references:
No references found.

4.4.3 Problem definition
All magnetic components behave as a dipole or multi-pole at large distances from the magnetic component. It is therefore necessary to shield the source of the magnetic field as good as possible.

4.4.4 Measures and insights
By combining the magnet track and the reluctance actuator one could reduce the amount of shielding used (one combined shielding is simpler then several separate). Also use of the fact that magnetic dipoles already cancel each other partly can be used. This also reduces the amount of shielding needed.

4.4.5 Embodiments
See figure.

reluctance
actuator

counter material

shielding,
see § 4.2.5

coil
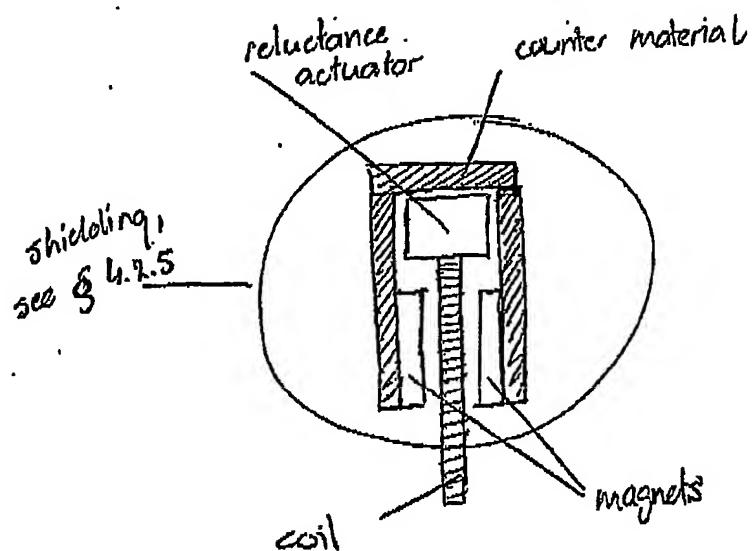
magnets

4.5   USING THE NUMBER OF MAGNETS IN ELECTROMAGNETIC DRIVE TO CONTROL MAGNETIC FIELDS (INVENTOR: ANGELO DE KLERK)

4.5.1   Know solutions
At this moment there are no known solutions.

4.5.2   Literature references:
No references found.

4.5.3   Problem definition
All magnetic components behave as a dipole or multi-pole at large distances from the magnetic component. By choosing the right magnet configuration one can limit the source of the magnetic field.

4.5.4   Measures and insights
The stay field can be reduced by choosing the right magnet configuration.

4.5.5   Embodiments
See figure.

large strag field →
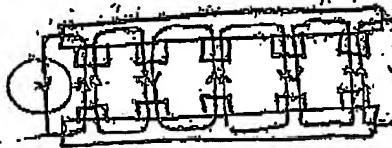
odd # magnets
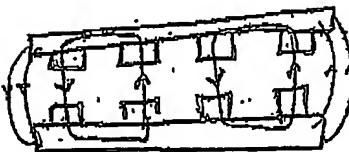
even # magnets

balanced fields
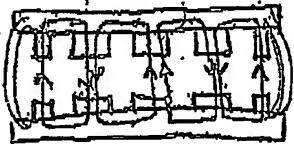
half magnet at the end

4.6 USING "HALF" MAGNETS TO CONTROL FIELD IN ELECTROMAGNETIC DRIVES (INVENTOR: JOHN COMPTER)

4.6.1 Know solutions
At this moment there are no known solutions.

4.6.2 Literature references:
No references found.

4.6.3 Problem definition
All magnetic components behave as a dipole or multi-pole at large distances from the magnetic component. By choosing the right magnet configuration one can limit the source of the magnetic field.

4.6.4 Measures and insights
The stay field can be reduced by choosing the right magnet configuration.

4.6.5 Embodiments
See figure in paragraph 4.5.5. By adding "half" magnets the end effects of the magnet track are influenced in a positive way. That is reducing the magnet source.

4.7 USING THE LENGTH OF THE MAGNET-PLATE OF ELECTROMAGNETIC DRIVE TO CONTROL MAGNETIC FIELDS IN THE VOLUME OF MAGNETIC FIELD REQUIREMENTS (INVENTORS: ANGELO DE KLERK, ARJAN BAKKER)

4.7.1 Know solutions

At this moment there are no known solutions.

4.7.2 Literature references:

No references found.

4.7.3 Problem definition

All magnetic components behave as a dipole or multi-pole at large distances from the magnetic component. By choosing the right length of the magnet track one can achieve low magnet fields at the point of interest.

4.7.4 Measures and insights

A magnet track has a different behavior at the end of the track in comparison with the middle of the track, there fore by choosing the right length of the magnet track on can obtain small magnetic fields at the point of interest.

4.7.5 Embodiments

See figure. By choosing the right length of the magnet track one can influence the magnetic field at the plane of interest.
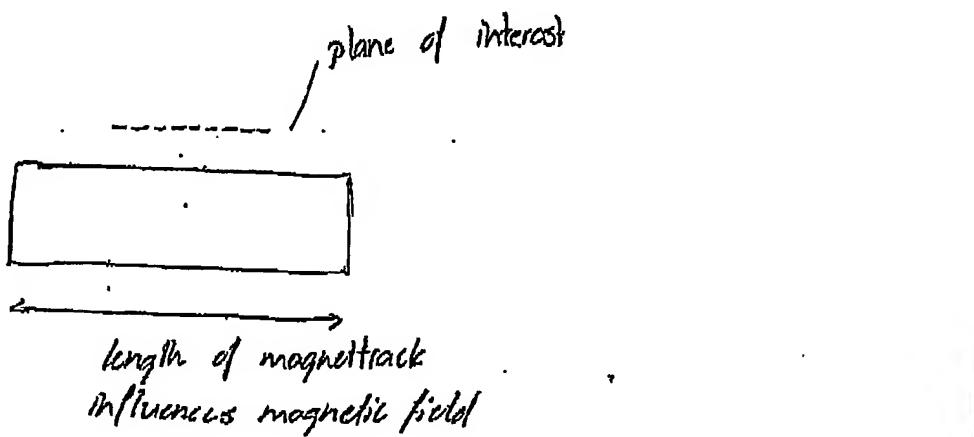
4.8 Using "MULTI-POLE"-CORES IN RELUCTANCE BASED MAGNETIC ACTUATORS (INVENTOR: ANGELO DE KLERK)

4.8.1 Know solutions

The most solutions present in patents is the use of an E-core reluctance based magnetic actuator. These actuators have a large distance between the teeth of the E-core. This causes large areas with remnant magnetism in the counter part of the actuator.

4.8.2 Literature references:

No references found.

4.8.3 Problem definition

The large areas of remnant magnetism cause a stray field.Measures and insights

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By decreasing the distance between the teeth (in the same volume) one can decrease the size of the areas with remnant magnetism.

4.8.4 Embodiments

See figure. By increasing the number of teeth in the core, the stray field is reduced.
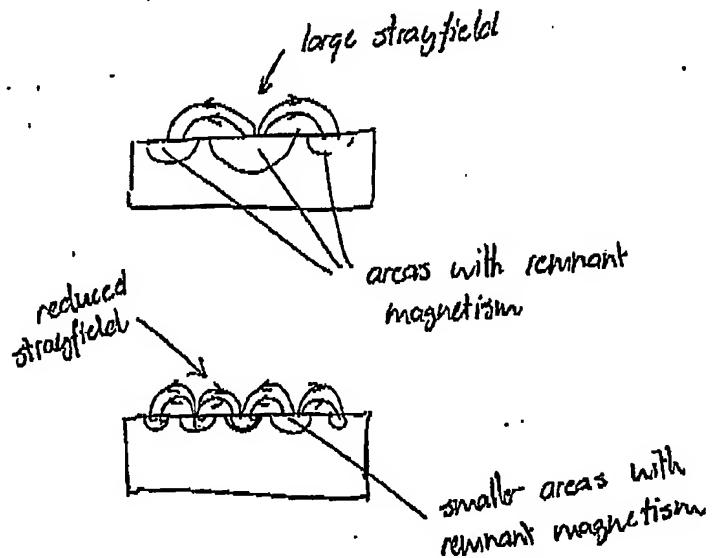
One could do this in the following way:
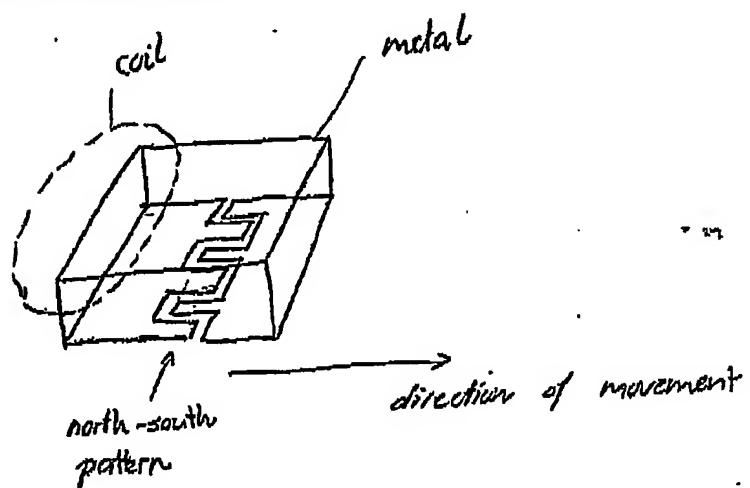
4.9 DEGAUSSING METHOD BASED ON DEGAUSS AUXILIARY DEVICE FOR GENERATING MAGNETIC FIELDS (E.G. MAGNETS AND/OR COILS) (INVENTOR: ANGELO DE KLERK, ARJAN BAKKER, JOHN COMPTER)

4.9.1 Know solutions
At this moment there are no known solutions.

4.9.2 Literature references:
No references found.

4.9.3 Problem definition
The large areas of remnant magnetism cause a stray field.

4.9.4 Measures and insights
The remnant magnetism can be reduced by degaussing the material. This can be done by a device which generates a magnetic field.

4.9.5 Embodiments
The field should look for the point which must be degaussed as follows (as function of the time):
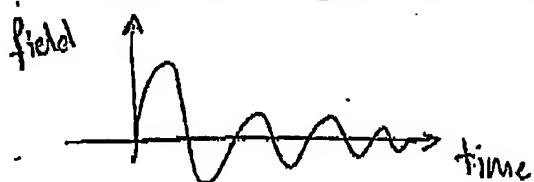
This can be done in the following way: a device generates remnant magnetism in a material, this can be removed by degaussing it by using a permanent magnet, which generates a field opposite to the remnant field.
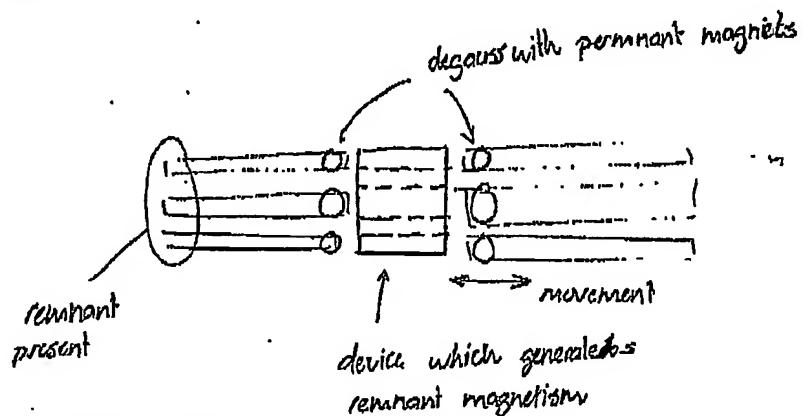

An other way is to do it by electro magnetic devices. By choosing a phase shift between the electro magnetic fields (sine / cosine), there will be no disturbance on the device which generates the remnant magnetism.
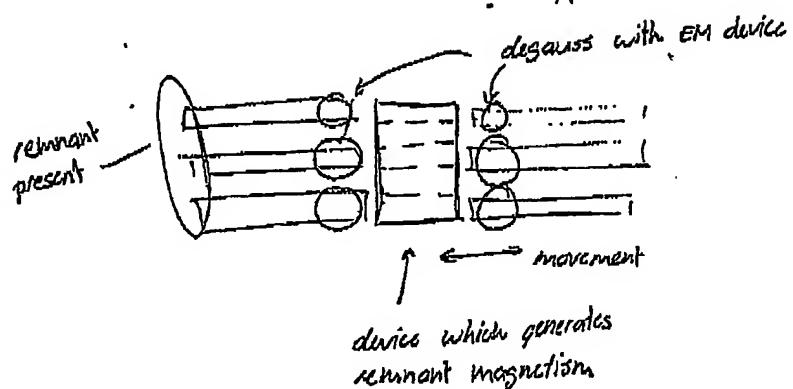
4.10 FLUX AMPLIFIER CONTROL (INVENTORS: HUUB VROOMEN, THOM WARMERDAM)

This invention is thought to be used in magnetically levitated structures (maglev structures). It can, however also be used when magnetic fluxes have to be controlled with high speed and precision in other applications.

4.10.1 Known Solutions

At this moment magnetic actuators are controlled by amplifiers that use the current in these actuators, or a signal that is based on measurement of this current, as a feedback signal. Because of the non-linear behavior of a magnetic actuator with respect to its current a non-linear system is created by using a current-controlled amplifier.

4.10.2 Literature references

No references provided

4.10.3 Problem definition

The non-linearity of a system consisting of a magnetic actuator and a current controlled amplifier makes it less well suited to be used in applications which demand high precision motion or (relatively) large motions between the actuator and the magnetic counterpart. Linearization techniques (described in other parts of this document) can help in some respects, this invention describes a technique that is based on changing the feed-back mechanism in the current amplifier.

4.10.4 Measures and insights

The force generated by a magnetic actuator based on the reluctance principle is relatively proportional to the flux generated by this actuator. Neglecting stray effects and saturation effects this flux multiplied by the (magnetically active) area of the actuator gives the force this actuator is generating.

This invention describes the possibility of changing the feedback loop in the current amplifier. Instead of measuring the current (e.g. by a LEM module or other device) and using this signal to control the current the amplifier is generating a signal representing the magnetic flux is used for feedback control.naturally both these signals can be used in parallel.

4.10.5 Embodiments

In the picture below the current situation in many maglev stages is shown:
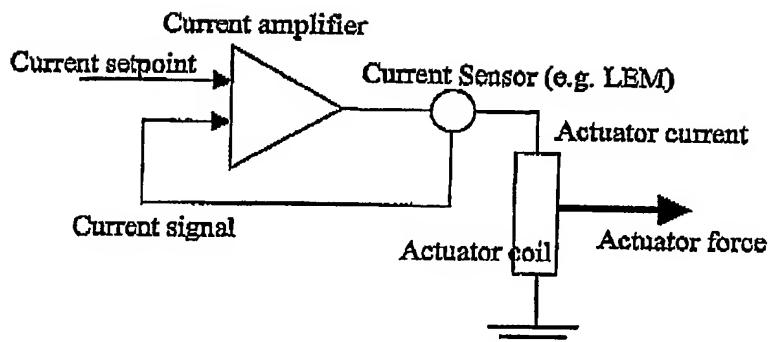
The picture below shows the first implementation of the invention, using a measurement of the actuator flux (e.g. Hall element):
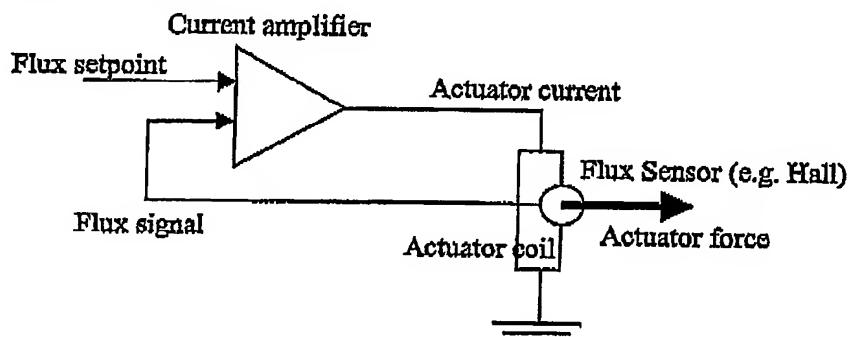

The picture below shows the combined use of current and flux signal for current feedback control:
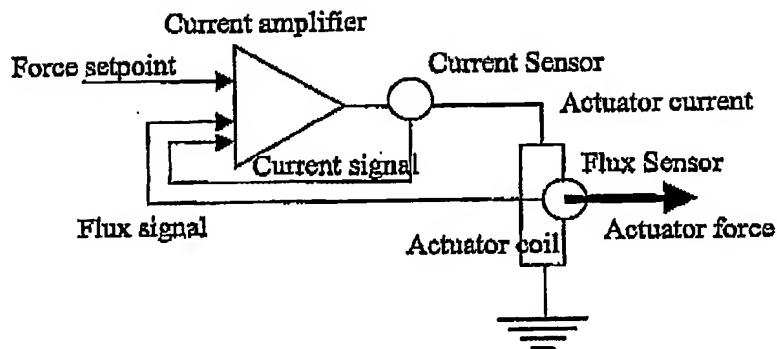
4.11 MODEL BASED CONTROL OF RELUCTANCE ACTUATOR TO ACHIEVE GAP-INDEPENDENT FORCE-CHARACTERISTICS (INVENTOR: JAN VAN EIJK, FRANK ROES, ARJAN BAKKER, DENNIS BOS)

Electromagnets generate a force according to the following formula:

$$F = C \cdot \frac{I^2}{x^2} = \frac{B^2}{2 \cdot \mu_0} \cdot A$$

in which

F = force

C = actuator constant

I = actuator current

x = distance to countermaterial

B = magnetic flux, B = B(x)

A = electromagnet surface

μ_0 = permiability
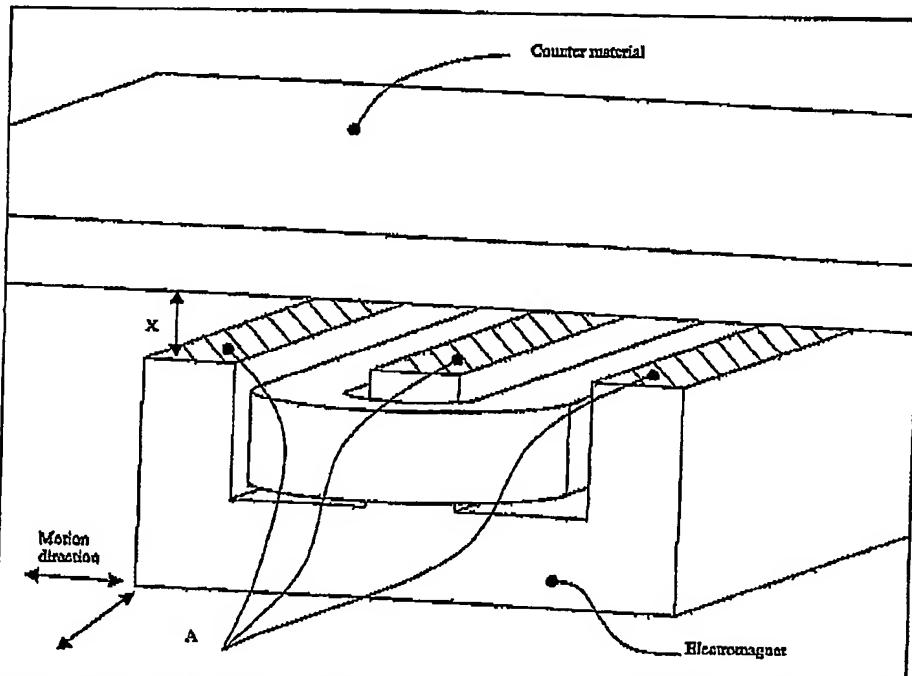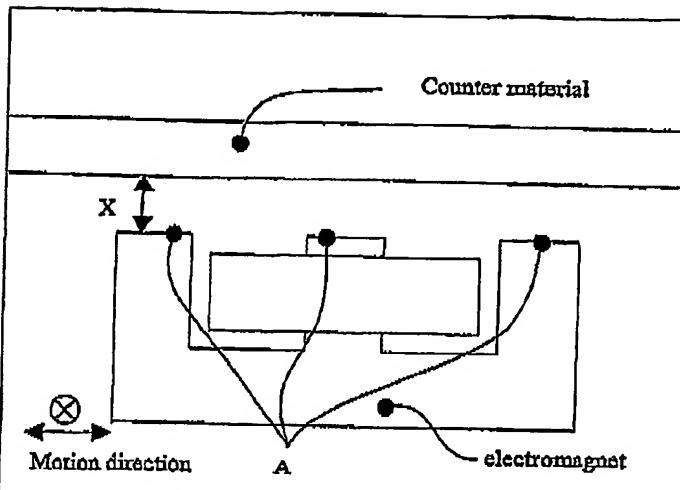
As one can see, the force is quadratic with current, distance and magnetic induction. This makes the control and initial levitation (start-up) of the actuator more difficult. Especially the distance is problematic.

Measures and insights
Linearization techniques can overcome this problem. At least two methods are possible.

Method 1:
Adapt the current as function of the air-gap between electromagnet. This means that the force command from the control loop is followed by the following algorithm, which calculates the current setpoint from the commanded current and measured air gap:

$$I = \sqrt{\frac{F \cdot x^2}{C}}$$

C can be constant but position and tilt dependant as well. This calculated current setpoint is used current command for the amplifier

Method 2:
The force command is followed by an algorithm, which calculates the corresponding magnetic flux:

$$B = \sqrt{\frac{F \cdot 2 \cdot \mu_0}{A}}$$

This flux command is the setpoint for the flux control loop, which uses the measured flux (measured with a Hall sensor) to control the flux to the value that it should be.

4.11.1 Known solutions
The use of maglev's in high accuracy environment is limited by the sensitivity for vibrations from the world. Often Lorentz actuators are used for the isolation.

4.11.2 Literature references:
No references

4.11.3 Problem definition
A moving maglev stage suffers in performance from a vibrating world and the performance is depending on the flatness of the guiding. Lorentz actuators can be as used as an alternative but the ratio of force versus heat generation is not efficient.

4.11.4 Measures and insights
By measuring the relative position of the maglev bearing towards the guiding rail, the commanded force by the controller can be kept constant using a model of the behavior of the maglev bearing. Instead of measuring the distance a flux measurement can be done to keep the commanded force constant. In this way the maglev bearing works as a vibration isolator towards the ground. The controller will run on a separate measurement towards the reference world.
Side advantage is that the counter surface of the maglev system can be very inaccurately made.
The maglev itself is a very efficient force generator with respect to the heat produced.

4.11.5 Embodiments
The maglev controller will take the commanded force and use the gap or flux measurement combined with a model of the behavior of the to maglev bearing element to compensate for gap variations. Also other measurements like speed, hall sensors etc. can be used to improve the model.
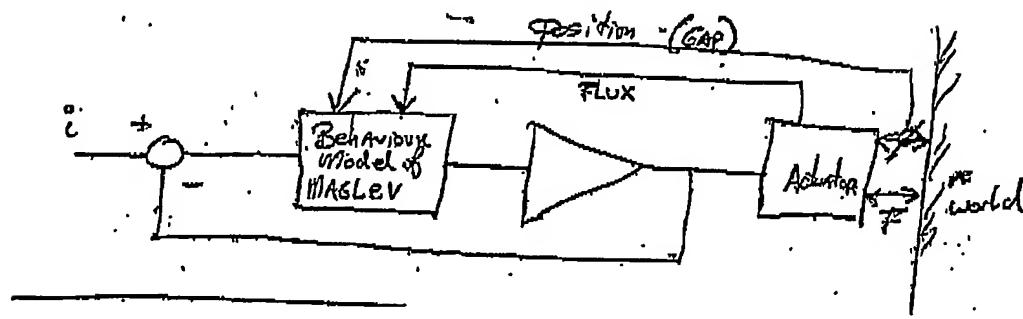
4.12 MODEL-BASED COMPENSATION OF DRIVE-FORCES (INVENTOR: ARJAN BAKKER, DENNIS BOS, FRANK ROES)

4.12.1 Known solutions

The use of maglev's in high accuracy environment can be limited by the limited stiffness of the bearings. The limited stiffness results in low dynamic performance.

4.12.2 Literature references:

No references

4.12.3 Problem definition

It's difficult to achieve high performance of a MagLev bearing system due to it's low stiffness. Generating force vectors not going through the center of gravity results in parasitic motions, which might not be reduced due to the limited stiffness of the bearings

4.12.4 Measures and insights

The dynamics can be improved by using a model based compensation for the drive forces which don't go through the center of gravity. In this way the bearings are used to compensate for not-aligned forces in a feedforward way, which gives freedom to place actuator forces while maintaining the same dynamic performance as the force would go through the center of gravity.

4.12.5 Embodiments
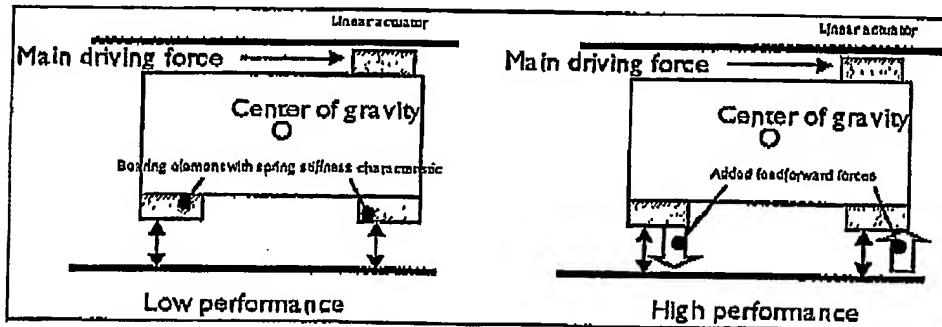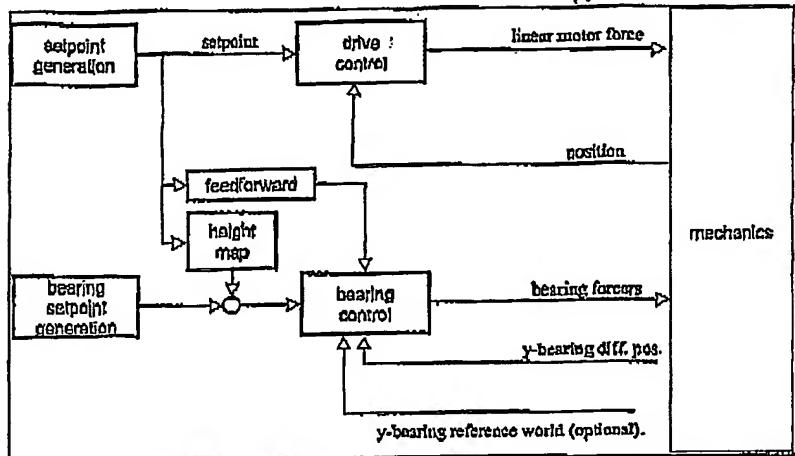
4.13 STAGE WITH GAP-INDEPENDENT CONTROL OF RELUCTANCE BASED ACTUATOR FORCE (INVENTOR: JAN VAN EIJK, ARJAN BAKKER)

4.13.1 Known solutions

Stages driven by Lorentz actuators are used to isolate vibrations from the world towards the stage. The main drawback is that Lorentz actuators generate a lot of heat. Which reduce performance or requires gravity compensators which may not be a vibration feedthrough in itself

4.13.2 Literature references:

No references

4.13.3 Problem definition

In high accuracy environment stages must be moved with as less disturbance from the environment as possible. Heat generation must be limited because it requires cooling (disturbance) and causes thermal expansions with both limit performance. Countermeasures (gravity compensators) still cause disturbance feedthrough.

4.13.4 Measures and insights

By using the element of 4.13 into a stage design the energy efficient Maglev actuator can be used instead of Lorentz actuators. Less countermeasures are needed so higher accuracy can be reached. Side effect are that the amount of parts is reduced, only steel counterpart (no magnets also a large reduction of parts).

4.13.5 Embodiments

The maglev actuator is used to levitate the stage while the main measurement of the controller structure comes from a reference.
1 DOF (Degrees of Freedom) example of the design, can be extrapolate to any other amount of DOF's.
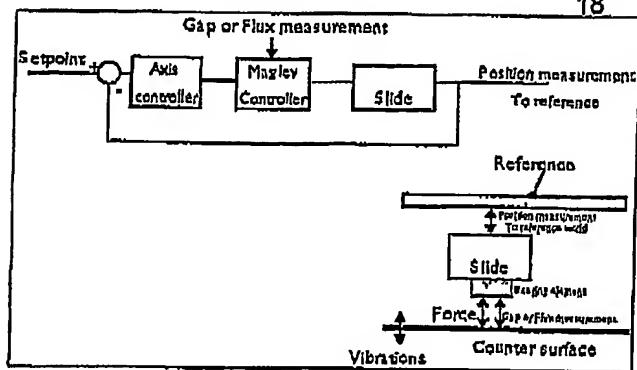
Variant with 6 maglev elements/actuators as bearing/shortstroke elements:
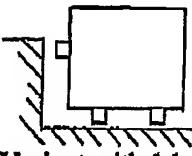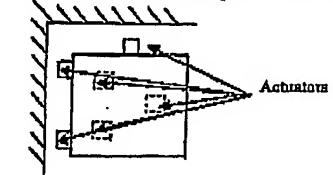
Variant with 1 longstroke actuator (linear motor) and 5 maglev as bearing/shortstroke elements:
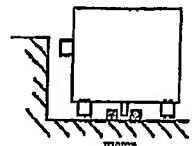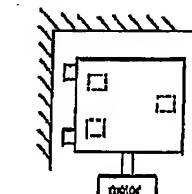

Variant with two longstroke actuators (linear motors) (moving direction+yaw) and 4 maglev as bearing/shortstroke elements.
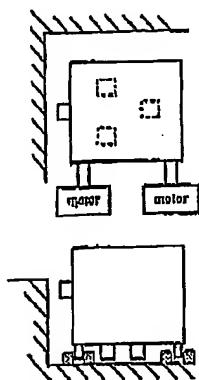
Variant with three longstroke actuators (moving direction+yaw+pitch) and 3 maglev as bearing/shortstroke elements.
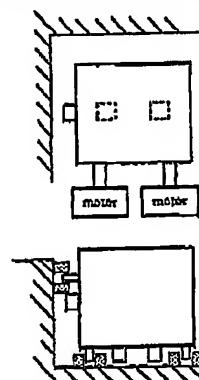
The countersurface can be both a fixed or a moving world (e.g. stacked stages) in all 4 concepts. Because of the isolation from the world this concept can also be used in overactuation a stage without introducing internal deformations.

4.14 LONG STROKE LORENTZ ACTUATOR AS BEARING (INVENTOR: ARJAN BAKKER, FRANK ROES)

4.14.1   Known Solutions
The system for electro-magnetic bearing using reluctance actuators is energy efficient. A disadvantage is the strong non-linearity of the actuator. Linearizing concepts have been shown. Using direct Lorentz-actuator (coil in magnetic field). this linearity issue may be solved.

4.14.2 Literature references
No references known

4.14.3 Problem definition

- Application of Lorentz actuators in electron-beam equipment has been avoided due to the stray-fields generated
- Short-stroke Lorentz actuators are used in stage-designers for high performance.

4.14.4 Measures and insights

The shielding solutions for magnetic fields, proposed in other paragraphs, makes the control of stray fields possible

Using long-beams with permanent magnets and moving coils allows a Lorentz actuator to act as a bearing for a long stroke motion

4.14.5 Embodiments

One actuator is shown in the diagram below. Combinations of such actuators will allow the control of position of the stage in all directions.
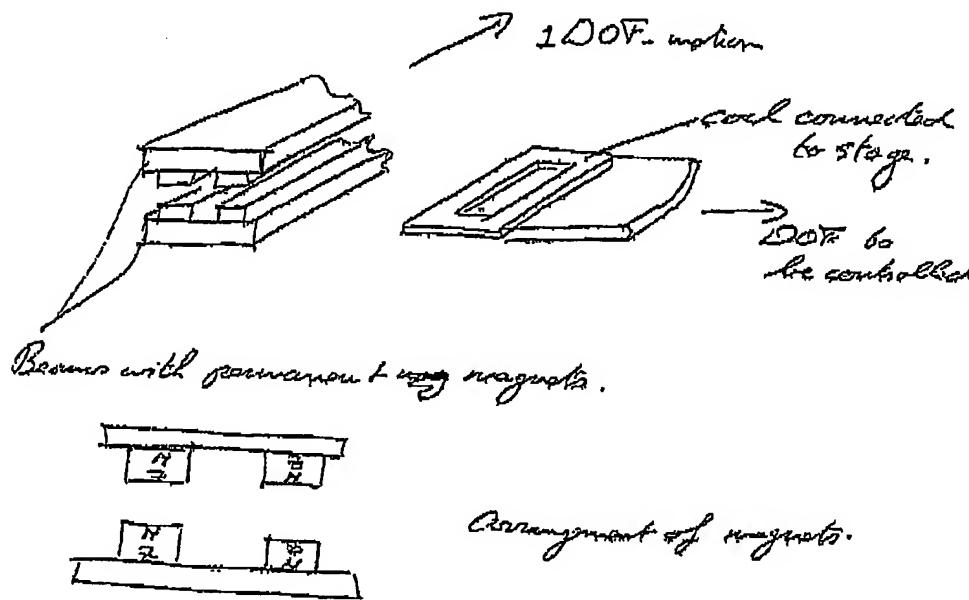
4.15 2-DOF PLANAR ELECTRO-MAGNETIC ACTUATOR (INVENTOR: JAN VAN EIJK, HUUB VROOMEN)

4.15.1 Known solutions

From the literature some ways of 6-DOF levitated stages based on Lorenz actuators are known. In fact, at the CFT a design of such an actuator was made and patented some years ago. Also many different forms of reluctance-type levitated stages have been shown in literature.

4.15.2 Literature references

None given.

4.15.3 Problem definition

Although very good in respect to controllability and linearity, the Lorenz type 6 DOF levitating stage has some disadvantages. One is the fact that some parasitic torques caused by electro-magnetic effects are introduced with motion over the magnet-plate (the so called dive-torques). Another aspect is that the center of gravity tends to be rather high away from the plane of electro-

magnetic forces. This means that the forces (e.g. for acceleration) generated in the actuators will not be uncoupled with respect to each-other in one or more directions.

4.15.4 Measures and insights

A normal linear motor, based on the Lorenz principle (e.g. normal three-phase motor) generates forces in the direction of motion by proper commutation of the currents in the three phases. The so-called commutation angle phi is depending on the position of the motor over the magnet plate (the design of the magnet-plate can be as in picture 1, but other arrangements (e.g. Hallbach) can be possible also). If the motor is of the iron-core type, also magnetic attraction forces are generated (figure 1). The design of the invention can be iron-less also however. By changing the phase of commutation of the three-currents however (by adding angles theta_one to theta_three), without changing the position of the motor over the magnet-plate, the force-vector can be tilted out of the plane of the magnet-plate (figure 2). The angle alpha can be controlled by proper calculation of the offset-angle theta_one to theta_three, taking into consideration the properties of the motor, the position over the magnetplate and the properties of the magnet-plate.

If the magnet-plate is not plane, the force-vector can be tilted towards the direction of the local normal-vector of the magnet-plate at the current position of the motor. This way, a force can be generated to give an acceleration towards the magnet-plate or away from it. Alternatively an acceleration (e.g. gravity) can be counteracted by this force, or a combination of both these effects. Because the magnetic attraction force is normally much larger than the force that can be generated by the Lorenz effect, a compensation force is necessary. This can be done by placing a second actuator of the type described above, which is generating about the same amount of magnetic attraction force in the opposite direction (figure 3).

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$I_1 = \hat{I} \cos(\varphi)$ $I_2 = \hat{I}\cos(\varphi + \frac{2}{3}\pi)$ $I_3 = \hat{I}\cos(\varphi - \frac{2}{3}\pi)$

picture 1

phase 1 phase 2 phase 3

Iron core

elect. coils

$F_{attraction}$

magnets

$I_1 = \hat{I}\cos(\varphi + \theta)$ $I_2 = \hat{I}\cos(\varphi + \frac{2}{3}\pi)$ $I_3 = \hat{I}\cos(\varphi - \frac{2}{3}\pi + \theta)$

picture 2

$F_{attraction}$

electrical force

F_B

magnet force

total force

picture 3

calculation of currents for upper cluster

upper magnet plate

attractive force of upper cluster

attractive force of lower cluster

lower magnet plate

calculation of currents for lower magnet plate
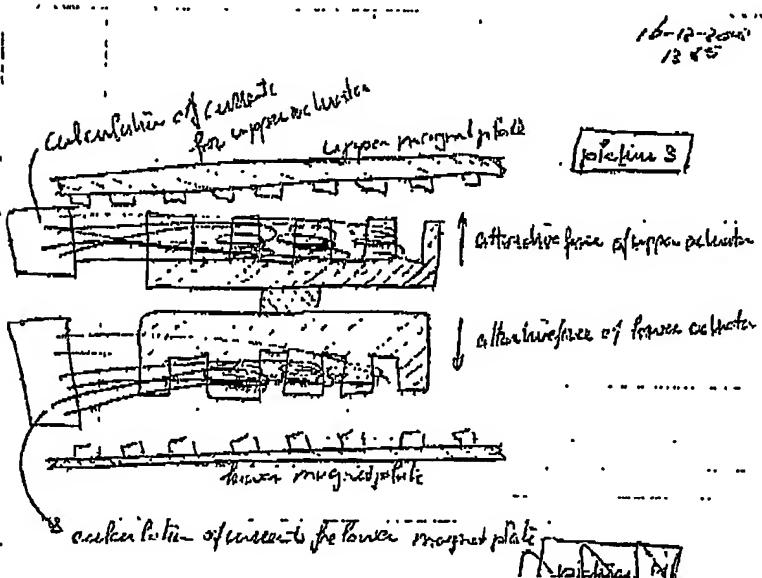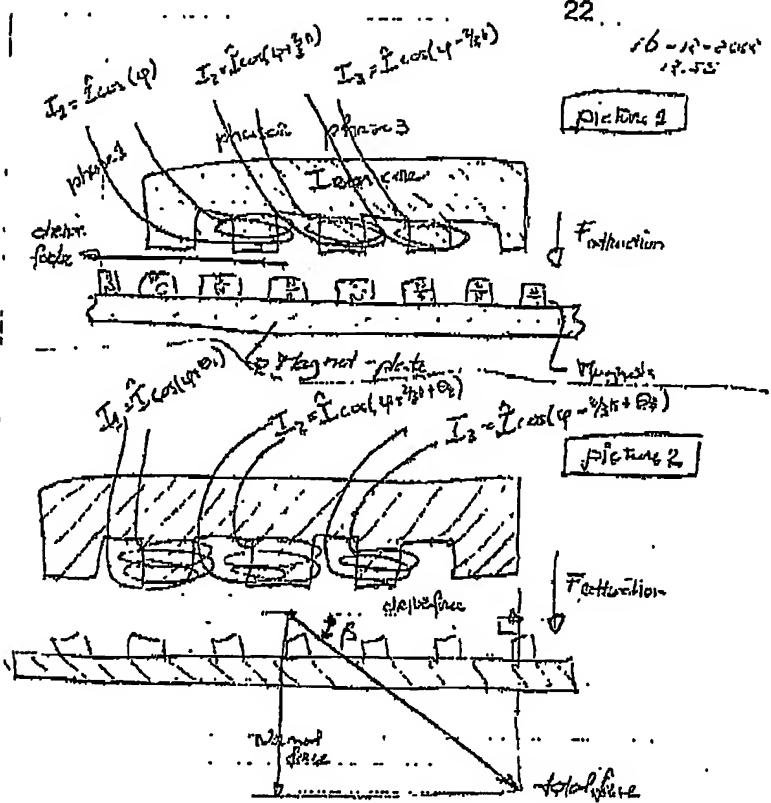
4.15.5 Embodiments

Figure 4 shows a stage design with 6 actuators of the design described above to control the stage in 5 DOF (y, z, rx, ry, rz) with Lorenz based levitation as described above and in 1 DOF (x-direction) with normal (Lorenz) linear drive force. Naturally this stage can also be used with another combination and orientation of the actuator units.
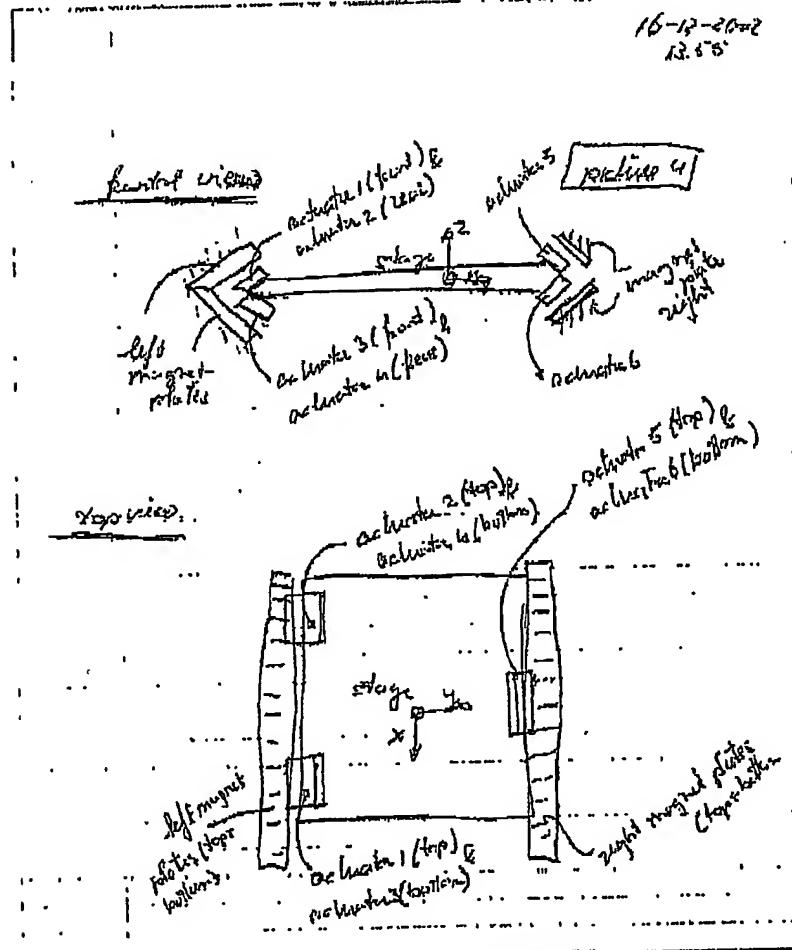
4.16 USING PERMANENT MAGNETS FOR GENERATING OFFSET FORCES IN ACTIVE MAGNETIC BEARINGS, USING DIFFERENT GAP DIMENSIONS FOR THE PERMANENT MAGNETIC SYSTEM AND THE ACTIVE MAGNETIC BEARING SYSTEM (INVENTOR: FRANK ROES)

4.16.1 Known solutions
No references known

4.16.2 Literature references:
No references known

4.16.3 Problem definition

Active magnetic bearing using electromagnets have the characteristic that when one applies a constant current, the force increases as the distance to the counter material gets smaller, since

$$F = C \cdot \frac{I^2}{x^2}$$

in which

F = force

C = actuator constant

I = actuator current

x = distance to countermaterial

This results in an unstable system in nature, and needs a stabilizing control loop to prevent the actuator from sticking to the counter material. This unstable behavior can be modeled as a negative stiffness, which needs to be limited since the outer loop has to compensate for it. The magnitude of the negative stiffness can be modeled as

$$K_{neg} = 2 \cdot \frac{F_0}{x_0}$$

in which

K_{neg} = the negative stifness

F_0 = the nominal force of the actuator

x_0 = the nominal air gap between actuator and countermaterial

Increasing the air-gap thus leads to a lower negative stiffness.

Using permanent magnets in combination with the electromagnets has the advantage that most of all of the levitating forces can be generated by the permanent magnet, leading to nearly no dissipation in the active actuator. A permanent magnet has the same instable characteristic as the electromagnet A similar formula for the negative stiffness is applicable for the permanent magnet as well (-> 1/x).

The problem is to end up with a system that is power efficient and has a low negative stiffness at the same time.

4.16.4 Measures and insights

The dissipation and the stiffness can be minimized by using a permanent magnet in combination with an active reluctance actuator, in which the permanent magnet generates up to 100 % of the nominal levitating force while the actively controlled reluctance actuator generates the residual force . The nominal air-gap of the reluctance actuator has be chosen very small, such that its power dissipation is minimal at already a negligible negative stiffness (since F_0 is very small) , while the permanent magnet air gap must be chosen much larger leading to a low negative stiffness in combination with no dissipation.
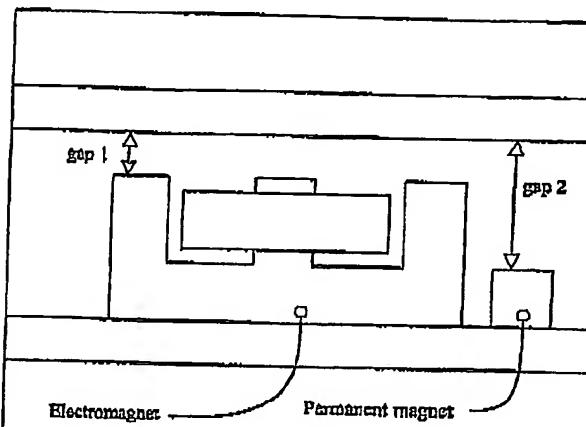
the new insight is to use permanent magnets in combination with active reluctance force actua-
rs in which the permanent magnets have larger air-gaps compared to the active reluctance force
tuators.

16.5 Embodiments
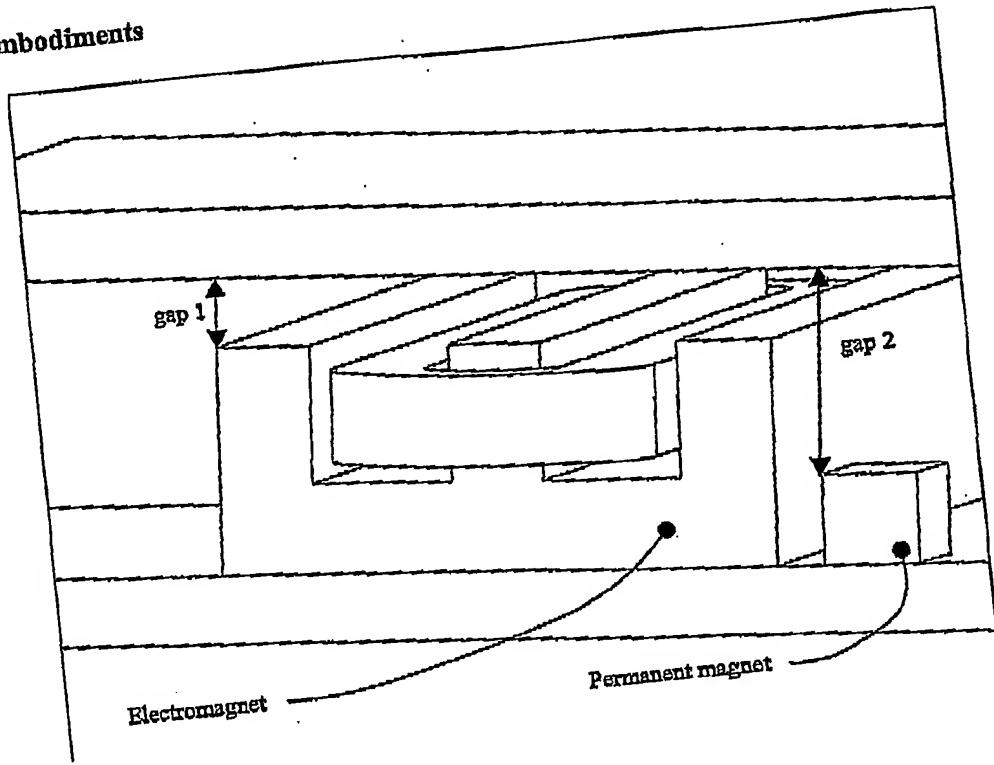
CLAIMS:

1.   Equipment, such as imaging equipment with charged particles (e.g. E-beam writers) and/or
inspection machines with charged particles and/or processing machines with charged particles (e.g.
semiconductor ion implantation equipment) and/or machining systems with charged particles
and/or medical equipment with the requirement of low magnetic fields (e.g. MR equipment or
Roentgen equipment), said equipment comprising a direct-drive electromagnetic drive system,
characterized in that the electromagnetic drive system comprises means for shielding and/or reduc-
ing magnetic fields originating in/generated by (components of) the electromagnetic drive system.